

# **FIRE PROTECTION CONSIDERATIONS IN THE DESIGN OF PLUTONIUM HANDLING AND STORAGE FACILITY HVAC SYSTEMS**

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## **Abstract**

*Unwanted fire in a facility that handles plutonium must be addressed early in the facility design. Such fires have the potential for transporting radioactive contamination throughout the building and widespread downwind dispersal. Features that mitigate such events can be severely challenged during the fire. High temperatures can cause storage containers to burst; a very efficient dispersal mechanism for radioactive contamination. The fire will also establish ventilation patterns that cause the migration of smoke and radioactive contamination throughout the facility.*

*The smoke and soot generated by the fire will enter the exhaust system and travel to the filtration system where it will deposit on the filters. The quantity of smoke generated during a typical multi-room fire is expected to blind most High Efficiency Particulate Airfilter (HEPA) media. The blinding can have two possible outcomes. (1) The air movement through the facility is reduced, compromising the negative pressure containment and allowing contamination to leave the building through doors and other openings; or (2) the filters collapse allowing the contamination to bypass the filtration media and exit the building through the filter plenum.*

*HEPA filter blinding during severe fires can be prevented or mitigated. Increasing the face surface area of HEPA filters will increase the smoke filtration capacity of the system, thus preventing blinding. As an alternative sandfilters can be provided to mitigate the effects of the HEPA filter bypass. Both concepts have distinct advantages. This paper will explore these two design concepts and two others; it will describe the design requirements necessary for each concept to prevent unacceptable contamination spread. The intent is to allow the filter media selection to be based on a comprehensive understanding of the four different design concepts.*

## **Introduction**

A dominant accident for most facilities that handle radioactive plutonium is uncontrolled fire. Such events are energetic with the potential to damage containment barriers and transport plutonium out of the building. Design features that are intended to prevent fires include automatic sprinklers, fire barriers, and detection systems if operator or fire department response is expected. With the exception of Maximum Foreseeable Fire Loss (MFFL) walls<sup>[1]</sup>, which are typically 4-hour blank construction, all of these features are incremental safety enhancements, none comprehensively prevent the occurrence of severe fires.

This paper explores four different design concepts that can be used to provide adequate fire protection for the HVAC system in a non-reactor nuclear facility. The paper presents a summary of the present DOE requirements for HVAC protection, a discussion of selected fire protection considerations in designing nuclear facilities, a description of the possible protection options with functional classifications, and conclusions on selection of the best design

option. It is the intent of this paper to provide a project team with the background necessary to fully evaluate the HVAC fire protection design options in a nuclear facility, however the paper is not intended to provide all of the design requirements.

## Requirement Overview

The principal DOE Orders and Standards that address fire safety are:

- DOE Order 420.1, *Facility Safety*<sup>[2]</sup>
- DOE Order 440.1A, Worker Protection Management for DOE Federal and Contractor Employees Facility Safety<sup>[3]</sup>
- DOE Order 5480.23, Nuclear Safety Analysis Reports<sup>[4]</sup>
- DOE Standard 3009-94, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports<sup>[5]</sup>
- DOE Standard 1066-99, Fire Protection Design Criteria<sup>[6]</sup>

DOE Order 420.1 establishes both the nuclear safety and fire protection goals\*. DOE non-reactor nuclear facilities are to be “designed and constructed so as to assure adequate protection for the public, workers, and the environment from nuclear hazards.” The fire protection goals are to minimize the potential for:

- (1) the occurrence of a fire or related event;
- (2) a fire that causes an unacceptable on- site or off-site release of hazardous or radiological material that will threaten the health and safety of employees, the public or the environment;
- (3) vital DOE programs suffering unacceptable interruptions as a result of fire and related hazards;
- (4) property losses from a fire and related events exceeding defined limits established by DOE; and
- (5) critical process controls and safety class systems being damaged as a result of a fire and related events.

DOE Order 440.1A requires that an acceptable level of safety from fire and related hazard be provided for DOE Federal personnel, DOE Contractor personnel and the public. Thus, DOE 420.1 and 440.1A provide the safety goals; the other orders and standards establish how these goals will be achieved.

Safety Analysis Reports (SARs) are an important feature of the DOE nuclear safety program. New SARs are prepared to meet DOE Order 5480.23 using a multi-step analytical process described in DOE-STD-3009-94. The primary purpose of the SAR is to identify and justify a set of controls “to ensure that a facility can be constructed, operated, maintained, shut down, and decommissioned safely and in compliance with applicable laws and regulations”<sup>[4]</sup>. Those engineered controls that lower the public risk below the evaluation guidelines are identified as safety class (SC) items. Those items that are identified as SC are typically very robust and possess a high degree of reliability and are expected to function as designed in accident environments<sup>[5]</sup>. Thus, reliabilities of 99.9 percent or better are expected, but not explicitly required.

DOE-STD-1066-99 provides guidance for fire protection design and construction at DOE facilities that are in the scope of DOE 420.1 and 440.1.<sup>†</sup> The standard is prescriptive in format, thus the requirements typically define how something should be installed or constructed. Principle features for nuclear facilities include: ventilation, limited use of combustible materials, fire separation, fire screens at filters, fire detectors with an activation setting of 190°F (i.e., use intermediate range: 175-249°F, 80-121°C)<sup>[8]</sup>, and deluge spray systems (automatic and manual).

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\* DOE Order 420.1 uses the term objectives. In this paper the term goal is being used to maintain consistency with *The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*<sup>[7]</sup>.

<sup>†</sup> DOE-STD-1066-99 cites DOE Order 440.1 rather than DOE Order 440.1A even though the approval date for DOE Order 440.1A is 27 March 1998.

There is no evidence that complete compliance with the above will result in a facility that meets all of the safety goals in DOE 420.1 and 440.1A. To bridge this gap, DOE 420.1 and DOE-STD-1066-99 require the preparation of a Fire Hazard Analysis. The intent of this analysis is to demonstrate that a facility meets the fire protection goals in the DOE 420.1 and 440.1A.

### Design Approaches

DOE 420.1, DOE 440.1A, and DOE-STD-1066-99 all refer to the National Fire Protection Association (NFPA) Codes, which consists of more than 300 codes and standards. They cover a variety of topics such as electrical design (NFPA 70), sprinkler systems (NFPA 13 and 25), fire detection systems (NFPA 72) and life safety (NFPA 101). The NFPA Codes prescribe a minimum set of fire safety requirements. Compliance with these documents is considered mandatory for most DOE facilities.

A primary standard for nuclear facilities is NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*<sup>[9]</sup>. This standard covers all aspects of fire protection for such facilities. It has few prescriptive requirements for the ventilation system design. Instead the performance-based requirement is: "The ventilation system shall be arranged such that the area containing dispersible radioactive materials remains at a lower pressure than that of adjoining areas of the facility before and during any fire incident." [paragraph 3-9.2]. There is no explicit requirement for a detection or suppression system to protect HEPA filters; instead it is left to the Fire Hazard Analysis (FHA) to determine the need for such systems [paragraph 3-9.6]. This is a change from the previous edition of NFPA 801, which mandated fire detection and suppression systems in HEPA filter plenums with a leading surface area greater than 16 ft<sup>2</sup> (1.49 m<sup>2</sup>). Thus, there is an inconsistency between NFPA 801 and DOE-STD-1066-99, which mandates suppression systems in HEPA filter plenums.

The inconsistency between the DOE and NFPA documents is partially the result of evolving technology and design approaches. Originally all fire safety standards were prescriptive; "build it this way and the facility is safe". As failures occurred or technology evolved new prescriptive requirements were introduced. Sometimes a protective feature that reduced fire risk in one application, increased other risks in a different application. In addition, this approach did not use an explicit definition of safe, sometimes requirements were introduced that mitigated the risk, but the risk reduction was not explicitly quantified. Thus, the benefit of some prescriptive requirements is uncertain so a new design approach was proposed. This new design approach that has been gaining favor in the fire protection community over the past 10 years is performance-based design<sup>[10]</sup>. Performance-based design allows the selection of fire safety features based on engineering principles. Thus, NFPA 801 was revised to accommodate a performance-based design approach.

In implementing performance-based design the protective features are selected to achieve the desired goals and acceptable level of risk. In evaluating this risk, the threshold for event incredibility must be defined. DOE-STD-3009-94 defines 1.0E-6/yr conservatively calculated and 1.0E-7/yr realistically calculated as the threshold for incredibility for external events. While there is no defined threshold for internal events such as fires, this external event criterion has been used for other SARs. In comparison, the frequency of multi-room fires in fully code compliant facilities is commonly in the Extremely Unlikely range (1.0E-6 to 1.0E-4 per year) and sometimes higher. Therefore multi-room fires are usually credible events that must be addressed in the facility SAR.

### Ventilation

Building ventilation is used to limit the undesirable movement of radioactive material (i.e., contamination). The normal flow movement is from areas of least contamination to highest contamination. Filtration systems are used to prevent the contamination from entering exhaust plenums and exiting the building. A typical arrangement will consist of supply and exhaust systems as shown in Figure 1. The filters on the supply system are intended to prevent the contamination spread out of the building in the event accidental reverse flow. The filters on the inlet to the exhaust plenum are expected to reduce the contamination entering the exhaust ducts, thus minimizing the buildup of contamination in the exhaust system.

The supply and exhaust air handling units are selected and balanced to maintain the required air movement to prevent undesired contamination migration. Typically, the exhaust system will handle slightly more air than the supply system to account for inleakage through doors and building joints. During accident conditions the ventilation

systems usually automatically respond to maintain the required negative pressure differential. If an exhaust fan fails to run, a standby fan will automatically start or supply fans will shut down as necessary. While this is often discussed as maintaining negative pressure differential, it is positive in-flow that is critical. This differentiation becomes very important during a fire where bi-directional flow can occur in doors and openings.

There have been several automatic responses to fire events that have been used in the design of nuclear facilities. The earliest is to shut off the supply air and close inlet dampers when a fire is detected. This has the effect of reducing the airflow through the facility, thus reducing the oxygen supply to the fire and limiting the fire size. If a significant fire size reduction is achieved the temperatures in the fire compartment will drop. The more recent concept is to maintain or increase flow during a fire event. This has the effect of reducing room temperatures by diluting the heated combustion gases as shown in Figure 2. As shown in this figure, it is possible, although undesirable, to optimize the air movement through the building to maximize the fire compartment temperature.

The restricted supply air approach (i.e., ventilation controlled) has several disadvantages. If the flow is not restricted adequately, it is possible that the flow reduction could increase, rather than decrease the fire temperatures. In addition this approach seldom will extinguish the fire, thus significant smoldering combustion is expected. This type of combustion produces carbon monoxide, rather than carbon dioxide, that has the potential to explosively ignite (i.e., backdraft). Thus, while restricting the supply air will often result in a less severe fire, the approach has an inherent instability (i.e., explosion potential) that can cause significant consequences.

The high air supply approach typically reduces the air temperature in smaller, less severe fires. Thus, the likelihood of these fires growing until they cause measurable contamination releases is reduced. Since such fires are generally anticipated (frequency  $> 1E-2/\text{yr}$ ), this is very desirable. This approach is possible because the combustion rate of most fuels is limited by the evolution of combustible gases (i.e., fuel surface controlled). The ventilation has other advantages. These include: removal of smoke allows fire fighters to be more effective, and removal of heat reduces damage to equipment and containers.

### **Fire Protection**

Adequate fire protection for a facility which handles radioactive material is accomplished with a mix of administrative programs and engineered features. These include:

- Minimization of fixed combustibles used for building construction
- Strict transient combustible controls and housekeeping after startup, to limit the potential for a fire occurring, and the severity of the fire should one occur
- Automatic suppression to control the fire early, before damage occurs
- Automatic fire detection to ensure proper response by operating and emergency response personnel
- Compartmentalization (fire areas) to limit the fire size to a manageable loss should automatic and manual suppression fail

While other fire protection features can be used, the above form the foundation for most nuclear facilities. In evaluating the fire protection for any facility, complete compliance with NFPA Codes and DOE-STD-1066-99 should not be considered to have achieved the required nuclear safety goals. Often it has been shown that strict compliance with the prescriptive fire protection codes and standards, does not result in attainment of the DOE nuclear safety goals.

### **Common Fire Scenarios**

Most facilities that handle radioactive material can expect to have at least one fire during its operating life. The size of this fire will vary from an incipient fire, which causes little damage, to full building involvement. Most fires will tend to be of the smaller magnitude. Thus, the anticipated fire (frequency  $> 1.0E-2/\text{yr}$ ) for most facilities will be an incipient fire that is fairly small (less than 300 kW), causes minimal damage, and does not result in contamination spread outside of the room of origin. An example of such a fire would be the ignition of waste in a glove box. During such an event multiple gloves can be damaged with some contamination release to the room. Usually this type of fire will be extinguished by facility personnel or burn until all nearby combustibles are consumed.

If the incipient fire is not extinguished, it will grow in size, possibly to involve the entire room of origin. Fires can then expand to involve two-rooms, multiple rooms and multiple fire areas. Each being more severe in terms of involvement. The frequency of these various severity levels will vary based on the combustible controls, operator presence and training, automatic fire detection, automatic fire suppression, fire barriers and the fire department response capability.

For most facilities a single room fire (i.e., one that does not cause flame damage outside the room of origin, but may cause smoke damage in nearby rooms) is an Unlikely event ( $1.0\text{E-}2/\text{yr} \geq \text{frequency} > 1.0\text{E-}4/\text{yr}$ ). Such a fire might burn for 20 minutes and consume most of the combustibles in the room. Credited controls to limit the extent of fire damage during such an event might include the building interior partitions, fire barriers, combustible loading limits, automatic suppression and fire department response. The amount of combustibles involved in such a fire is expected to be greater than 100 kg.

The mass that must be burned to cause HEPA filter pluggage will vary with the type of material. For wood, a best estimate value of 27 kg burned will plug one filter (24" by 24" face area). For flammable and combustible liquids a conservative (not bounding) value of 5 kg/filter is suggested.<sup>[11]</sup> For plastics, the value is expected to be between these two values. If 100 kg is consumed in a fire, the amount of smoke produced would be expected to plug the room filter, disrupting the room air flow and forcing smoke into adjacent rooms. This smoke would then travel throughout the ventilation zone and to the zone HEPA filters. It is expected that in most facilities there will be an adequate number of zone HEPA filters (i.e., bank) such that pluggage of the filters will not occur for a single-room fire.

A fire that involves more than one room will be either Unlikely or Extremely Unlikely ( $1.0\text{E-}4/\text{yr} \geq \text{frequency} > 1.0\text{E-}6/\text{yr}$ ) depending on the fire protection provided. Such a multi-room fire will evolve a significant quantity of smoke, which will travel to the filtration system. If a two-room fire is assumed to involve 500 kg of combustibles, then based on 20 kg/filter it will require a zone HEPA filter bank of more than 25 units to preclude pluggage. Thus, for most facilities pluggage of the zone HEPA filters is problematic during a two-room fire and expected if three rooms are involved. Pluggage of the zone HEPA filters may result in a loss of building ventilation, thus allowing smoke and radioactive contamination to exit the building through doors and other openings, or filter collapse and the subsequent release of smoke and radioactive contamination through the building ventilation stack. Either alternative is considered undesirable.

### **Limiting Fire Risk**

Fire protection programs typically focus on prevention to reduce fire risk (e.g., housekeeping, ignition controls). Even suppression efforts (operator fire extinguisher training, automatic suppression systems, etc.) are intended to intervene prior to the fire causing significant damage, thus preventing the severe fire event. This approach of providing multiple protective programs and design features is used in both general industry and DOE facilities. Thus, most facilities that are considered to have an adequate level of fire protection exhibit a strong defense-in-depth strategy.

The need for a strong defense-in-depth occurs because no one fire protection program or design feature fully dominates the risk profile. The majority of fire protection programs and design features have success probabilities in the single digits. The probability of a detection system successfully initiating an emergency response in an industrial facility<sup>[12]</sup> is 0.8. Fire doors successfully close and latch with a probability<sup>[13]</sup> of 0.8. The probability of successful manual control of a fire with hand held fire extinguishers<sup>[14]</sup> is 0.6. Automatic suppression is an exception with a success probability<sup>[15]</sup> of 0.96. The result of this is no single fire protection component or program can be credited as the safety class item that successfully prevents the multi-room fire.

### **Mitigating Fire Consequences**

Container integrity is one method of mitigating the effects of a severe fire. If all plutonium were placed in robust containers, which are designed to contain their contents during the most severe fire, the fire consequences would meet the evaluation criteria. Even accounting for some statistical failure rate, the evaluation criteria could be achieved. Unfortunately, this approach is not viable in a facility that processes plutonium, or where the storage container design is already fixed.

If container integrity is not practical, the only remaining confinement features are the building structure and the ventilation system. To successfully prevent the release of radioactive contamination to the environment, both the exterior walls and ventilation system must be credited. For a plutonium handling facility, the exterior walls and roof will typically be heavy reinforced concrete. Thus, they can be readily designed to withstand any credible fire with little practical project impact. The design requirements for the ventilation system are discussed below.

For the ventilation system to successfully mitigate radioactive contamination spread will require the following:

- Air handling equipment to maintain the building at a negative pressure during and following the fire
- Filtration media that allows ventilation flow during and following the fire (i.e., does not plug)
- Control of the air temperatures approaching the filtration media, to avoid filter media failure by excessive temperature
- Filtration media that do not collapse as a result of smoke loading during a severe fire.
- Screens or water sprays that prevent hot brands from damaging filters

### **Protection Options**

To successfully accomplish the five above requirements will require one or more of the following design approaches:

- Option 1 – Provide HEPA filter protection per DOE-STD-1066 and demonstrate that the automatic water spray system reduces the effect of pluggage.
- Option 2 - Ensure that there is adequate face area to preclude unacceptable pluggage during a fire and adequate dilution to preclude excessive temperatures at the filters.
- Option 3 – Prevent fire propagation to more than 3 rooms. Demonstrate that a fire in 2 rooms will not result in excessive temperatures at the HEPA filters, or unacceptable plugging.
- Option 4 – Provide a sandfilter and exhaust system that is sized to accommodate the design basis fire.

Option 1 and 2 are very similar and rely on the integrity of the HEPA filters. Option 3 relies on preventing the fire from becoming too large for the ventilation system to handle. This was the design option that was proposed for the APSF. Option 4 has been successfully used at SRS for many of the major nonreactor nuclear facilities.

There have been multiple papers and standards that discuss the protection of HEPA filters by active water spray components (Option 1). While most demonstrate successful protection, some indicate that water sprays can also accelerate filter pluggage. In addition, the seal failure temperature ( $122^{\circ}\text{C}$  for urethane<sup>[6]</sup>) is very close to the upper value of the fire detectors ( $121^{\circ}\text{C}$ <sup>[8]</sup>), so excessive exposure may occur without spray system activation. Thus, the successful protection of HEPA filters by active water spray is problematic. It is possible that these issues can be resolved, but not with high certainty.

The concept behind Option 2 is very simple. Provide enough HEPA filter face area and any possible fire can be accommodated. To make such a system work will require some method to prevent hot brands from damaging the HEPA filters. This could be accomplished by fire screens. It is expected, but not confirmed, that the entire filter bank capacity can not be on-line at one time, since the efficiency of the HEPA filters will drop for some particle sizes at low flow rates<sup>[16]</sup>. Thus, to make a large face area concept work it may be necessary to install a switching system to transfer airflow from “plugged” to “clean” filters.

For both Option 1 and 2, the filter housings must be protected from direct (external) fire effects, since the options only provide for internal fire protection. This external protection might be accomplished by redundant parallel trains separated by fire rated construction, high-integrity, automatic fire suppression, or any other high reliability method. Without such protection a fire in the room containing a HEPA housing has the potential to allow an unacceptable release.

In evaluating the above options, the importance of the various design features need to be ranked. In developing a ranking criteria the Functional Classification process in DOE-STD-3009 can be useful. This process identifies the following levels of protective features.

- Safety Class (SC) – Controls that reduce the unmitigated public risk to below the evaluation guidelines
- Safety Significant – Controls that reduce the unmitigated worker risk to acceptable level or provide defense-in-depth to a safety class protective feature
- Design Feature – Controls that provide for a significant reduction in risk, but are not required to be safety class or safety significant.

Table 1 provides a ranking of the importance of the design features for the four ventilation options. In performing this ranking the functional classification level of safety significant and design features were combined into a category considered important to safety (I). An additional category Operating Feature (O) was also created. Features in this category might limit risk but are not required for facility risk to be considered acceptable.

In evaluating the options, there were several features that must be safety class for all possible options. These include the building structure, the exhaust fans, the supply system filtration (or backflow prevention) and the exhaust filtration. Thus at least four features must be safety class. In evaluating each option the respective number of SC features is 10, 11, 11 and 6. (See Table 1.) Thus, the sandfilter approach requires the fewest SC features.

**Table 1.--Design features for possible protective concepts**

Function	SSC	Item Description	HEPA			Option 4 HEPA & Sandfilter
			Option 1 Spray	Option 2 Dilute	Option 3 Suppress	
Containment	Building structure	Exterior	SC	SC	SC	SC
		Fire barriers	I	SC	SC	O
	Ventilation	Fire partitions	O	O	SC	O
		Supply fans	O	O	O	O
		Exhaust fans	SC	SC	SC	SC
		Fire dampers	O	O	SC	O
	Control dampers	Supply	O	SC	O	O
		Exhaust	SC	SC	O	SC
	Ductwork	Internal to building	SC	SC	I	I
		External to building	SC	SC	I	SC
	Filtration	Supply HEPA *	SC	SC	SC	SC
		Exhaust HEPA	SC	SC	SC	O
		Sandfilter	...	...	...	SC
Fire protection	HEPA	Automatic spray	SC	I	I	...
		Manual spray	O	O	O	O
		Fire screen	SC	SC	SC	...
		Demister	SC	SC	SC	...
	Building wide	Sprinkler	O	O	SC	O
		Detection	O	O	SC	O
		Number of safety class SSCs			10	11

\*or backflow prevention

### Design Considerations

To provide an acceptable level of safety in a plutonium handling facility, the design and construction of the HVAC system must be robust and will require the focus associated with most safety class systems. To accomplish this will require a special effort by the project team in design, procurement, installation and post-installation qualification.

Strict compliance with consensus standards, while necessary, will not necessarily provide the required operational robustness.

In selecting between the four proposed design options the evaluation metrics are: construction cost, operating cost, and project risk. The following sections focus on the project risk metric since cost estimates can be readily developed once the design and operating costs are understood. There are many factors that contribute to the project risk metric. These include:

- State-of-the-art for design concept (Has it been built before?)
- Robustness of the design approach
- Extent of design data available
- Flexibility of the design
- Acceptance by reviewers
- Potential for an unreconcilable issue (Will the concept reach a deadend?)
- Complexity

In judging complexity the number and type of protective controls will be used, where it is preferable to use engineered controls (i.e., structures, systems and components, SSC) rather than administrative controls. Where engineered controls are used passive are preferable, since they usually have the greatest reliability. Active controls can be further separated into two sets, those requiring a change of state following the accident initiator and those that do not. The order of preference is thus:

1. Passive SSC (e.g., building structure)
2. Active SSC not requiring a change of state (e.g., continuously operating exhaust fan)
3. Active SSC that must change state after the event initiatory occurs (e.g., emergency generator)
4. Administrative controls

Option 1 (full reliance on the HEPA filter spray system) relies on active components to be successful. As mentioned above, the difference between the specified detector temperature range and the filter failure temperature is minimal, thus the system may not activate on demand. This shortcoming is considered a potentially unreconcilable issue representing a very high project risk. This high risk merits exclusion of this design option from further consideration. In addition, there is limited test data demonstrating the robustness of this design approach and it has been criticized by the DNFSB<sup>[17]</sup>.

There are no non-reactor nuclear facilities that rely on Option 3 (Safety class building suppression system) so the concept has not faced review by outside agencies. The approach was proposed for APSF, however the concept was never fully developed into a final design. Thus, it is uncertain if outside agencies would accept this concept. Based on the lack of demonstrated success using Option 3, the project risk is considered very high and further consideration of this option is not recommended.

### **HEPA Filters**

Option 2 is a design concept that can be readily constructed. While there is some uncertainty in the smoke plugging data, excess capacity can compensate for this shortcoming. In addition, it is expected that active safety class components may be needed to switch the flow prior to filter pluggage. The flexibility of this design is limited and the costs for this option have not been developed however the concept should be acceptable to reviewers.

The major issues that must be addressed by the design team to successfully implement an all-HEPA filter design are:

1. Design Data – There is little empirical design data on the performance of HEPA filters during fires. The data that is available is based on HEPA filters that were fabricated prior to the pricing pressure for clean rooms and DOE budget cuts.
2. Life Expectancy – There has been an issue raised on the life expectancy of HEPA filters<sup>[18]</sup>. Resolution of this issue may affect the final design and operating approach for a design based solely on HEPA filtration.
3. Active Components – The integrity of the filtration system is dependent on active components to shift airflow between filter sets. The design of these components is expected to require additional effort by the design team.
4. Housing Protection – No acceptable method to adequately reliable fire protection of the HEPA filter housings from direct fire effects has been identified.
5. Prefilter Credit– It is possible to credit the prefilters to mitigate the smoke loading on the HEPA filters. If so, the prefilters are expected to be safety class and additional design data would need to be developed.
6. Administrative Controls – The robustness of the filtration system is sensitive to the administrative controls that limit transient combustible loading and project configuration controls to maintain the planned fixed combustible loading. This requirement will require special efforts by the design team and the facility operator.

#### **Sandfilter**

Option 4 is a successful design concept that is used at multiple DOE sites and has been the subject of multiple reviews by the DNFSB<sup>[18]</sup> and other groups. With the exception of the exhaust fans, all of the Safety Class features are passive, thus the concept is very robust and flexible. Recent cost estimates for an integrated sandfilter design are not available. The cost estimates for recent projects have been for standalone attachments to facilities that have multiple stages of HEPA filtration. Thus, the estimates do not show the cost savings associated with reducing the complexity of the HVAC system.

The major issues that must be addressed by the design team to successfully implement a combined HEPA filter and Sandfilter design are:

1. Design Standard - No formal design standard has been published so it will be necessary for the project team to generate a design basis.
2. Seismic Qualification – There is limited information on how sandfilters perform during earthquakes. The project team will need to generate empirical data and analysis to demonstrate that sandfilters perform adequately during seismic events.

#### **Conclusions**

Four different design options to provide adequate fire protection for the HVAC system at a non-reactor nuclear facility have been evaluated. Two approaches are considered viable: an all-HEPA filter system that relies on dilution to prevent excessive temperatures during a fire, and a system that relies on a combination of HEPA filters and a sandfilter. The other options are reliance on the HEPA filter water spray fire suppression system, and a building-wide safety class fire suppression system. Both of these latter options are considered to have an unacceptably high project risk.

The all-HEPA filter HVAC concept will require multiple passive and active safety class components to limit fire risk. Some of these would include building structure, exhaust fans, exhaust filtration, supply filtration (or backflow protection), fire screens, and active control dampers to redirect flow when filters plug.

The sandfilter HVAC concept will require the fewest number of safety class components to limit the fire risk. The major safety class components would include the building structure, exhaust fans, external ventilation ducts and the

filter. With the exception of the exhaust fans all of these components will be passive, thus the system can be considered very robust.

Both the all-HEPA filter HVAC concept and the sandfilter HVAC concepts can be successfully constructed and operated to achieve the desired risk profile. Since both have advantages, the selection between these options is best made by balancing construction costs, operating costs and the project risk.

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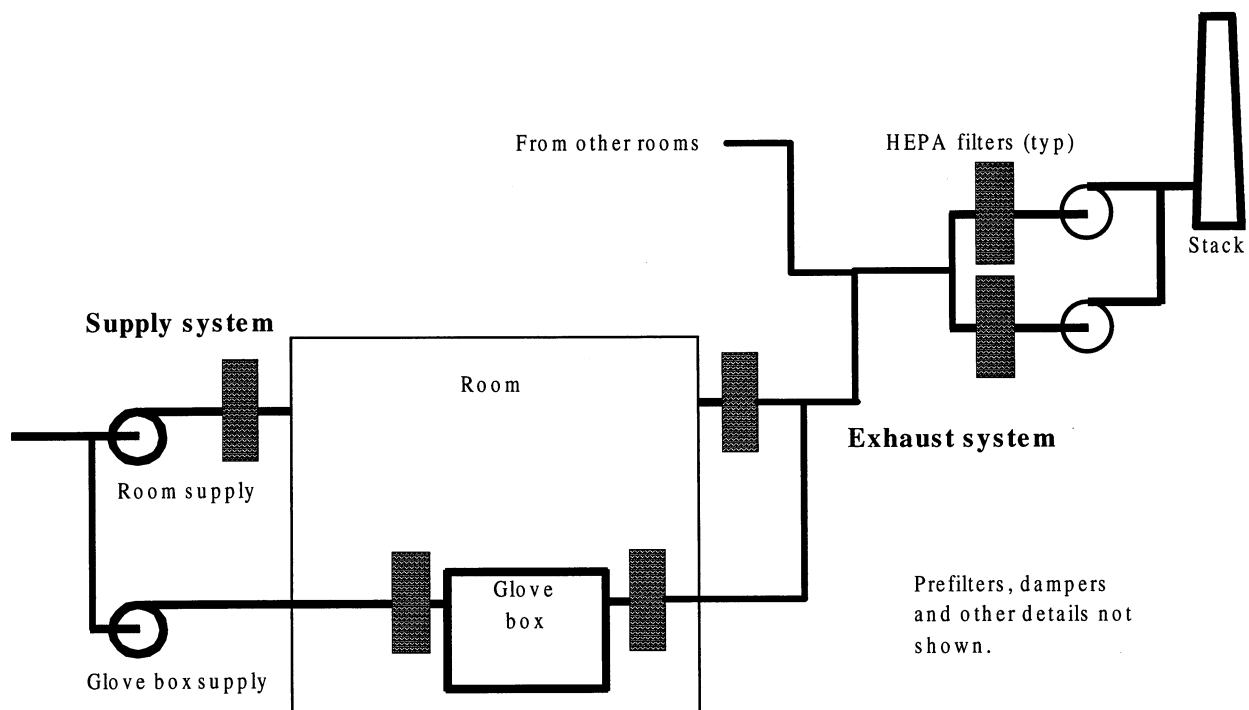


Figure 1, Example ventilation arrangement

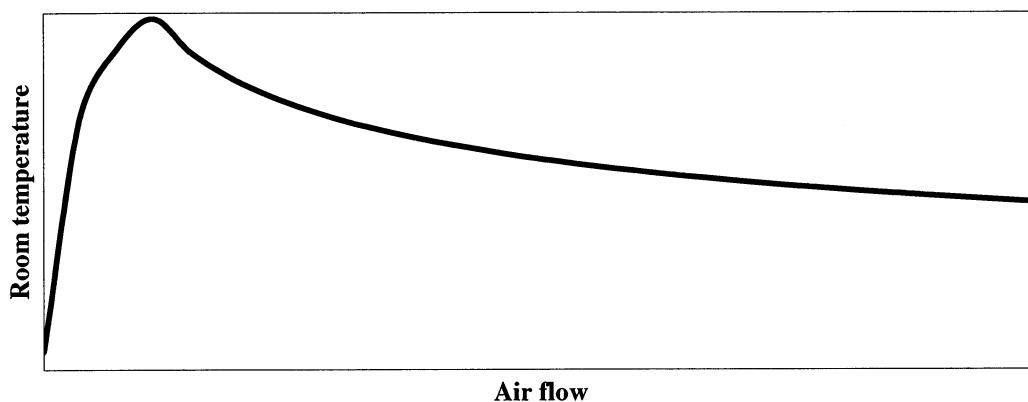


Figure 2, Ventilation effect on room temperature